Chapter 10
The Starkey Experimental Forest and Range: Long-Term Research to Meet the Needs of Managers

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Abstract As the current concern over climate change illustrates, there is a need, sometimes unforeseen, for the development and maintenance of long-term data sets. Coupling long-term vegetation data sets with long-term wildlife demographics allows scientists to evaluate potential cause–effect relations between changing landscapes and wildlife populations. Vegetation data sets contain important variables often included in habitat effectiveness models that predict the value of a landscape for a particular wildlife species. In this chapter, we focus on Starkey's research history and long-term research activities on wildlife and rangeland resources as case examples of applied research that has addressed societal needs for ecosystem services. In 1939, Pickford wrote a letter that initiated discussions on the Starkey Cattle and Horse Allotment in the Whitman National Forest as suitable for a research station to develop information on the management of cattle summer range within the ponderosa pine (*Pinus ponderosa* Dougl. ex. Loud) type. In 1940, the Starkey Experimental Forest became a reality. The major research problem to be addressed was the overgrazing of mountain ranges. The current research trajectory was initiated in 1989 with the building of a game-proof fence and development of a telemetry system to monitor ungulate movements. The initial studies focused on perceived conflicts between deer and elk, and timber harvest and livestock grazing. Current research focuses on the role of ungulates as chronic ecosystem disturbance agents and their interaction with episodic disturbance to alter successional trajectories. Also included is the confounding role of human disturbance in modifying ungulate distribution across landscapes.

Keywords Livestock grazing · Deer · Elk · Wildlife habitat · Forage quality · Herbivory

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10.1 Introduction

National leaders and policy makers are facing profound issues regarding people and the environment. Among these are impacts of climate change, biodiversity, and the value of ecosystem services. Managers are considering these developing issues while addressing immediate problems such as increasing wildfires from fuels accumulation and exotic weed invasions. Fire suppression, wildfires, livestock grazing, logging, road construction, recreation, and many other human disturbances have singly and interactively caused extreme alterations in plant community composition of forests, in turn, causing a cascading effect on wildlife. As management scenarios are developed to deal with these present and emerging problems, managers need better knowledge about the impact of those practices on nontarget species and their habitats. As the current concern over climate change illustrates, there is a need, sometimes unforeseen, for the development and maintenance of long-term data sets. Cody and Smallwood (1996) cite two reasons for long-term data collection: (1) The opportunity occurs to observe important but rare events, e.g., episodic disturbance (fire, insect outbreaks), before and after and (2) detection of processes that evolve/unfold slowly, e.g., climate change.

Vegetation structure and composition are the basic ingredients of wildlife habitat. All wildlife use vegetation for shelter, either for the security aspects (hiding) or for thermal regulation. Herbivores are, of course, dependent on vegetation for food and the carnivores are dependent on the vegetation to produce their prey species. Coupling long-term vegetation data sets with long-term wildlife demographics allows scientists to evaluate potential cause–effect relations between changing landscapes and wildlife populations. Vegetation data sets contain important variables used in habitat effectiveness (HE) models to predict the use or other values of a landscape for a particular wildlife species. These models are effective planning tools to identify and evaluate landscape options for managing plant communities, associated habitats, and other important ecosystem properties. Swetnam et al. (1999) have shown benefits from the analysis of long-term vegetation data sets. As an example, they cited fire scar chronologies being widely used to justify and guide fuel reduction and natural fire reintroduction in forests. Climate change and the need to account for its potential effects in land-use planning have particularly brought sharp focus to the lack of available data (Powledge 2008).

Experimental forests and rangelands, managed by the USDA Forest Service, form a network of locations amenable to long-term data collection across many of the major ecosystems of the continental USA, Alaska, and Hawaii (Lugo et al. 2006). Historically, long-term understory/rangeland data collection on these sites encompassed a 10–15-year period and typically focused on different intensities of livestock grazing or timber management. Common variables included those for weather, structure, and composition of merchantable timber and associated silvicultural regimes; production and composition of livestock forage and changes related to grazing intensity (including exclusion of grazing); and livestock gains (Klipple

and Costello 1960; Martin and Cable 1974; Skovlin et al. 1976). In some cases, the effects of livestock management on wildlife were reported (Skovlin et al. 1976).

Truly long-term data sets (20+ years) for wildlife and understory and range vegetation are rare but do exist. Linkhart and Reynolds (2004, 2007) studied return rate, fidelity, dispersal, and longevity of flammulated owls on the Manitou Experimental Forest in Colorado. The H.J. Andrews Experimental Forest served as one of the important study areas for long-term research on the biology and ecology of the spotted owl (Anthony et al. 2006). Studies examining understory/rangeland vegetation successional trends have been carried out on a few experimental ranges (Buffington and Herbel 1965; Angel and McClaran 2001). Unfortunately, the status of many older studies or supporting data collections, in terms of longevity and variables monitored, are incompletely documented. These records often are boxed and archived in warehouses and other locations generally inaccessible to scientists (personal communication, Richard Oakes, Site Manager, Manitou Experimental Forest, Woodland Park, CO).

Pearson et al. (2008) reported on grazing and excluded plots at the Fort Valley Experimental Forest in Arizona that were sampled from 1912 to 1941 and rediscovered and resampled from 1996 to 2007. Johnson (2003) illustrates the value of long-term data collection on vegetation change in his description of 90 years of plant succession on green fescue (*Festuca viridula* Vasey) grasslands in the subalpine ecological zone of the Wallowa Mountains in Oregon, where changes in sheep grazing over time resulted in dramatic changes in plant community composition. Gibbons and Beck (1988) reported on long-term plots that were established between 1915 and 1932, continuously read until 1947, and only a portion read annually until 1979 when the collection was discontinued.

A number of reasons have likely contributed to the scarcity of long-term data sets. Personnel turnovers and a lack of ownership of long-term studies that may only be sampled every 5 or 10 years, coupled with limited funds available to hire personnel for data collection, are likely causes. Universities, which undertake much of the natural resource-related research, tend to receive support for short-term studies because the university reward system promotes research leading to frequent publications (Fribourg 2005; Vavra 2005). Federal research agencies, alternatively, commonly focus their work on longer-term projects that are tied to experimental areas (Klade 2006). Another shortcoming of some long-term data sets with infrequent monitoring is the lack of concomitant weather and soils statistics (Mueggler 1992). Sharp et al. (1990) pictorially demonstrated the link that growing season and annual precipitation have on species composition and productivity on a research site in southern Idaho.

The objective of our study is to review research on the Starkey Experimental Forest and Range that has been driven by the needs of land and wildlife managers and to discuss some of the management implications. We focus on Starkey's research history and long-term research activities on wildlife and rangeland resources as case examples of applied research that has addressed societal needs for ecosystem services.

10.2 Research Program

10.2.1 The Starkey Experimental Forest and Range: The Early Years

The Pacific Northwest Research Station (PNWRS) was established in Portland, OR in 1924 (Skovlin 1991). This coincided with a national movement to have a Forest Service research organization present in each major forested region of the country. Even previous to this time, consideration had been given to establishing a western range experiment station in the Blue Mountains. In 1936, the US Senate Document 199 focused national attention on the deteriorating state of the western range. The problem of overgrazing mountain ranges was added to the list of concerns that the PNWRS was to address. Gerald Pickford came to the PNWRS in 1936 and was joined in 1937 by Elbert “Bert” Reid. Much of their summer field seasons were spent east of the Cascades visiting problem sites and assessing research needs. These men were among the first to identify excessive elk use of mountain meadows in the Elkhorn Mountains (Pickford and Reid 1942). In 1939, Pickford wrote a letter that initiated discussions on the Starkey Cattle and Horse Allotment in the Whitman National Forest as suitable for a research station to develop information on the management of cattle summer range within the ponderosa pine (*Pinus ponderosa* Dougl. ex. Loud) type. In 1940, the Starkey Experimental Forest became a reality, but World War II interrupted research at Starkey. After the war, research focused on improved forages for livestock production. Joseph Pehanec became the chief of range research for the PNWRS in 1945. His efforts led to the addition of “Range” to the Starkey Experimental Forest title. Today Starkey remains the only experimental forest and range.

Pehanec later served as the first president of the Society for Range Management. Robert Harris joined the range research staff in 1946. He would go on to be the deputy chief of research for the Forest Service.

In the early 1950s, Jon Skovlin, rangeland scientist, and Gerald Strickler, ecologist (Fig. 10.1), came to Starkey and conducted important research there for the next three decades. They would build on the earlier research on overgrazing. In 1953, the first long-term study on cattle grazing methods and stocking rates was initiated (Skovlin et al. 1976). Cattle were grazed under deferred rotation and season-long grazing systems and at three different stocking rates for each method for 11 years. The study also included a no-grazing control. Prior to the study, most cattle grazing was season-long because there was no scientific support for a rotational system. Deferred rotation at moderate stocking rate provided better protection of the forage base and soil resources. This was the first study to show the impacts of cattle grazing on the forage resource in forests and how that in turn affected deer and elk distribution and food habits. Cattle stocking rates and the associated deferred rotation system described in this study are still in use by National Forest range managers.

Fig. 10.1 Range Ecologist Gerald Strickler clipping standing crop during an early grazing study on the Starkey Experimental Forest and Range

10.2.2 The Starkey Experimental Forest and Range: Recent

Long-term wildlife research was initiated by Evelyn Bull in 1973 with her study of pileated woodpeckers. This species was selected as a management indicator species for older forests by some regions in the USDA Forest Service because of its use of large-diameter hollow trees and snags for nesting and roosting. Large, hollow trees and snags often are felled for safety reasons during forest management activities or are felled for firewood use. Consequently, detailed research regarding the species' ecology and habitat requirements was needed. The initial study lasted 10 years (Bull 1987), with resampling done in 1989–1990 (Bull and Holthausen 1993) and 2003–2005 (Bull et al. 2007). The resampling efforts allowed the evaluation of long-term forest management practices on the woodpecker and its habitat. These studies revealed the importance of snags and down logs to the ecology of pileated woodpeckers. Forest Service woodcutting permit and logging regulations were modified to maintain large snags for nesting habitat. Recommendations for forest stand composition for optimum pileated woodpecker habitat were made. Landscapes with extensive tree mortality from insect outbreaks continued to be acceptable pileated woodpecker habitat if they were not extensively harvested. Timber harvesting that provides retention of coarse woody debris (snags and down wood) will maintain acceptable pileated woodpecker habitat.

Beginning in 1976, intensive studies of livestock performance and seasonal forage nutritional quality were initiated in cooperation with Eastern Oregon Agricultural Research Center, Oregon State University, to evaluate existing grazing systems and provide information for the development of new systems for riparian zone improvement (Walburger 2002). This research was driven by the emergence of concern for the condition of streams and associated riparian corridors across the western USA. In northeastern Oregon, many streams are spawning and/or rearing habitat for endangered salmon and steelhead stocks, which made the research more critical.

As part of this research, Holechek et al. (1982a, b) discovered a nutritional disparity between the forage on north-facing versus south-facing grassland slopes as the grazing season progressed. Forage quality deteriorated more rapidly on grasslands than in forests, but the grasslands responded with nutritionally better regrowth to late summer and fall precipitation than did the forests. Utilizing each slope at its nutritional optimum improved livestock weight gain over cattle allowed free choice of both slopes. This increased production provided some offset to the increased cost associated with fencing if streams required total protection. If livestock permittees were required to initiate rest rotation or deferred rotation systems over season-long grazing to improve riparian conditions, the question arose on whether weight gains would be similar between systems or if the forced movements required of a rotation system would reduce overall summer weight gain. Research at Starkey indicated no detrimental effects on animal production with the use of rest rotation or deferred rotation grazing systems (Holechek et al. 1987).

The 25 years of study (Walburger 2002) revealed to managers and livestock producers that the use of nutritional calendars in the design of grazing systems could increase beef weight gains. At the same time, prudent use of nutritional calendars reduces cattle use of riparian zones while maintaining the desired stocking rate and grazing area.

10.2.3 The Starkey Project

In 1973, Jack Ward Thomas arrived in La Grande, OR, as a research wildlife biologist and project leader at the Pacific Northwest Research Station's Range and Wildlife Habitat Laboratory. Thomas's duties included oversight and coordination of research at Starkey.

Earlier that year, eastern Oregon's dry forests experienced an extensive outbreak of the tussock moth. Inch-long tussock moth caterpillars had voraciously defoliated thousands of acres of Douglas fir (*Pseudotsuga menziesii,* Mirbel, Franco) and grand fir (*Abies grandis,* Dougl., Lindl) trees, leaving forests brown, ailing, and, at worst, bare in their wake. Intending to clear the landscape of dead and dying trees, National Forest managers found their efforts challenged by the recently enacted National Environmental Policy Act, which required that environmental effects of major actions on public lands be examined and disclosed before actions commence.

At the same time, eastern Oregon's elk population was increasing, raising fears among livestock producers that their cattle would face competition for forage. Wildlife managers were equally concerned about the availability of forage, but their fear was that livestock posed a greater threat to the browse that elk and deer needed to survive. Moreover, increases in timber harvest and intensive building of roads to facilitate these harvests worried managers that elk and deer were losing thermal and hiding cover. These roads had the secondary effect of opening up tracts of deer and elk habitat to hunters, offering unprecedented access. By the end of eastern Oregon's 2-week-long elk hunting season, managers were startled to find as few as 1

or 2 bulls remaining for every 100 cows. To managers, declining herd productivity, not forage, emerged as the greatest threat to the region's elk population.

Donavin Leckenby, a research project leader with the Oregon Department of Fish and Wildlife, worked in the same building as Thomas and was studying elk and their habitat in northeastern Oregon. Leckenby was a seasoned biologist who had previously completed an extensive study of mule deer behavior and habitat use in central Oregon. Leckenby and Thomas—two scientists representing two different and diverse agencies and research styles—found common ground for research on the emerging issues of elk habitat, timber harvest, and potential competition among elk, mule deer, and cattle. Leckenby brought a naturalist's perspective, which he obtained from his direct observation studies of elk. These studies also generated a sense of frustration in him—he would watch elk but did not have the experimental controls necessary to determine if their behavior was based on the preference for a habitat or if that habitat was a requirement for the well-being of the elk.

In the 1980s, a dramatic intersection of management and policy, wildlife and livestock interactions, and multiple resource use occurred as part of major changes in National Forest management. State and Federal agencies, livestock growers, and sportsmen were at odds over various issues pertaining to the management of National Forest lands. Thomas and Leckenby took stakeholder and agency input from a series of regional meetings as well as from informal correspondence. Martin Vavra, then with the Eastern Oregon Agricultural Research Center, Oregon State University, was contracted to develop the problem analysis "Forage allocation for big game and livestock in northeastern Oregon." A significant portion of the problem analysis was a compilation of elk, mule deer, and cattle issues identified by ranchers, county extension agents, and personnel from Oregon Department of Fish and Wildlife, Forest Service, Bureau of Land Management, and Isaac Walton League.

In response to the cumulative input, Thomas and Leckenby formulated major research questions to address both the sustainability of elk and deer herds and the perceived conflicts with timber harvest and livestock grazing. The research questions centered on the effects of timber harvest and roads on elk, deer, and cattle productivity and distribution; on how these large animals use landscapes and food sources; and on the effect of breeding bull elk on herd productivity (Rowland et al. 1997). Controlled experiments were needed to separate animals' preferences from requirements. Controlled experiments could only be conducted in a controlled environment; and the idea of a game-proof fence around Starkey was initiated. In July 1986, then Forest Service Chief Max Peterson approved the project. With that, the Starkey Project was born.

With the support of his colleagues, Thomas turned his attention from being a scientist to serving as the Starkey Project's promoter. First, he needed to persuade his supervisors and the National Forest System (NFS) that developing a 40-square-mile fenced research laboratory together with an automated telemetry system to monitor animal movement—as he proposed to do with the Starkey Project—was a worthwhile investment. As Thomas saw it, this field laboratory would yield data that could help managers make the inherently difficult decisions that encompass management of landscapes, elk, deer, and cattle. Ultimately, the NFS agreed and

Fig. 10.2 Elk fitted with a global positioning system (GPS)-based transmitting collar. GPS has replaced the original telemetry system

provided funding from regional and national levels. The land that Thomas proposed to fence off and change human activities as part of the project was a long-time hunting and camping area. Convincing local residents of the importance of this project was, clearly, a tough sell.

As funds were being allocated to the Starkey Project and its studies, Larry Bryant, a wildlife biologist at the La Grande Laboratory, worked with the La Grande District Forest Service to develop a timber sale around the site's perimeter. It was the longest clearcut in Forest Service history, 26 miles in length. By removing the trees, Bryant was able to install a game-proof perimeter fence down the middle of the cleared corridor, which helped to guard against wind-thrown trees damaging the fencing structure. Bryant then secured a track machine that was able to dig hundreds of post holes and navigate the rough landscape at the Starkey Project site.

The Eastern Oregon Agricultural Research Center, branch station of Oregon State University, already a long-term cooperator, provided 100 cows to the allotment on Starkey with a portion of those fitted with radio telemetry collars. Center staff provided both scientific and technical support to the project with leadership in cattle-related studies.

Over the course of the first 20 years of the project, 40 cooperators participated in the research. Included were universities, state wildlife and parks agencies, NFS, private industry, Native American tribes, federal agencies, and the Oregon Cattlemen's Association.

With the fence complete, the next challenge was to invent an automated telemetry system that could monitor animal movement frequently and accurately. The Starkey Project's success hinged on the ability to remotely and efficiently monitor exactly how elk, deer, and cattle moved and interacted across the vast project landscape in response to manipulative experiments. Bryant worked with a Texas company to develop a telemetry system that was based on a government-operated navigational aide to aircraft and ships at sea (Rowland et al. 1997). The system permitted the Starkey Project researchers to gather almost continuous movement data of large animals that had been fitted with transmitting collars (Fig. 10.2). With the

fence and a reliable and advanced system for capturing data in place, the Starkey Project was operational.

The original four research problems, the influence of roads and traffic on deer and elk; the influence of intensive timber management on deer, elk, and cattle; exploring forage allocation among cattle, deer, and elk; and the influence of bull age on breeding success and calf crop of elk, were addressed in the work conducted during the 1990s (Rowland et al. 1997). The enclosure fence and the automated telemetry system were critical to the success of the research (Thomas and Wisdom 2005).

10.2.3.1 The Effect of Roads and Traffic

Fitting female elk with radio collars and recording their location several times each day allowed scientists to record more than 100,000 elk locations in relation to distance from roads. Data gathered were used (1) to test the hypothesis that elk use increased as distance from a road increased; (2) to evaluate the standard elk HE model that used a road density variable as one of the predictors of elk distribution; and (3) to examine potentially confounding effects of different spatial patterns of roads on HE model performance (Rowland et al. 2000).

The road density component and other variables in the HE model had undergone little validation even though the model had been used extensively by NFS planning and management. In the HE model, there was no component for addressing the variability in the spatial pattern of roads across a landscape. Female elk consistently selected areas away from open roads in both spring and summer. In spite of this relationship, little or no significant relations existed between the number of elk locations and HE scores based on road density. From this study, the formulation of distance bands was developed, offering managers a more spatially appropriate scale for predicting road effects on elk distribution. This new approach gave managers a better estimation of the true landscape scale habitat available to elk.

Roads per se are not really the issue in moving elk. In fact, it is the traffic on those roads that initiates movement (Wisdom et al. 2005b). Within Starkey, traffic counters were placed in selected locations on roads open to traffic (Rowland et al. 1997, 1998). Counts of traffic were used to characterize the rate of traffic on each road segment. Animal movements were again recorded with the automated telemetry system. Traffic rates as low as one vehicle per 12 h caused elk to move farther from the roads, and elk avoidance of roads increased with increasing rates of traffic (Wisdom et al. 2005b). Deer responded in the opposite manner, with increased selection toward roads of higher traffic rates, which was shown to be related strongly to elk avoidance rather than a reaction to roads or traffic (Johnson et al. 2000; Wisdom et al. 2005a).

This study reinforced the findings of Rowland et al. (2000, 2005) and also illustrated that mule deer habitat selection was strongly influenced by elk distribution. The findings of these two studies would strongly influence management decisions on road management in Forest Plans across the western USA and lead to new research dealing with the influence of human disturbance on distribution and behavior of elk and mule deer.

10.2.3.2 Intensive Timber Harvest

At the inception of the Starkey Project, intensive timber harvest was practiced on much of the Forest Service lands in the western USA. Wildlife managers raised concerns over the loss of thermal and hiding cover and the potential negative impacts on elk productivity. The intensive timber harvest study was initiated on 1,416 ha acres enclosed by a game-proof fence so that elk and cattle utilizing the study area could not leave and were forced to reside within the area being logged. This allowed scientists to directly measure elk and cattle response to the timber harvest treatment (Wisdom et al. 2005c). The following summary of methods and results provided in this study are from Wisdom et al. (2005c). Radio-collared animals utilized the study pasture before harvest (1989), during timber sale planning and layout (1990–1991), during harvest (1992), and during postharvest management (1993–1996). Timber harvest occurred on 50% of the forest lands in the study area and was primarily shelterwood and seed tree regeneration cuts. Cattle and elk distribution before, during, and after timber harvest was monitored and data were utilized to map spatial distributions. Both elk and cattle in the study area were weighed annually and those weights were compared to those of elk and cattle grazing the main study area.

Elk distribution changed substantially during timber harvest with the use concentrated on the study area's outer boundaries. Elk distribution also became more diffuse during harvest; nearly twice as much of the study area was within the 50% use volume compared to the period before harvest. Elk decreased their use near roads during timber harvest when traffic rates increased substantially. They also utilized steeper slopes during harvest indicating a selection for greater security. After harvest, the elk not only returned to the western half of the study area but also increased their use in the interior portion, the area which was largely unused during harvest. Elk distribution was more diffuse after harvest than before but less diffuse than that during harvest.

In contrast to elk, cattle showed little change in distribution during all periods of study. The areas of highest concentration remained consistent before, during, and after timber harvest. Unlike elk, cattle showed no evidence of selection of areas with characteristics of greater security from humans.

If timber harvest has a negative impact on elk or cattle then one metric to use as an indicator would be decreased weight gains. Cattle, (cows and calves) were weighed on and off Starkey in both the main study area and the intensive timber study area each year. Likewise, elk (cows in spring, cows and calves in fall) were weighed before turn out onto the study areas and again in the late fall when they entered the feedground. The main study area served as a control to the intensive timber harvest treatment. If timber harvest caused a treatment effect in weight gains, then within a given year weight gains in the intensive timber harvest treatment would be expected to decrease or increase compared to those in the main study area. The direction and degree of variability in annual weight gains was generally consistent between the two study areas for both species. Weight gains then were largely affected by weather patterns that affect annual changes in forage biomass and nutritional quality.

An important aspect of intensive timber harvest is the development of a more open landscape and the opportunity for hunters to harvest more elk with less effort. Elk vulnerability to hunter harvest increased with timber harvest. For the years before timber harvest, hunter success averaged 22 % and required an average of 19 days to achieve that level of success. During timber harvest, success increased to 35 % with only 9 days required to achieve that success. After timber harvest, hunter success was 32 % and was achieved in 14 days. The data just reported were for hunter entry to the study area on foot only. When vehicle use was allowed, the success increased to 54 % with only 14 days required to reach that. For landscapes with extensive timber harvest or fuels treatments that greatly reduce hiding cover, a combination of road closures and limited hunter entry is likely to be effective in preventing overharvest.

This research, in conjunction with other studies that evaluated the physiological response of elk to varying levels of thermal cover (closed forest canopy; Cook et al. 1998), revealed that elk productivity will not be impaired by intensive timber harvest. This research illustrated the importance of the Starkey Project because enclosure fencing provided the opportunity to differentiate between preference and requirement in regard to canopy cover and elk. At times, elk prefer habitats that provide security cover in the form of a dense multistoried canopy but do not require this stand structure for homeostasis. The study shifted potential management emphasis from thermal cover retention to management that reduced elk vulnerability to hunter harvest. Reduced vulnerability is achieved through the retention of security areas and restrictions on motorized access. These goals could be reached by planning timber harvest activities in time and space such that a mosaic of seral stages is maintained to provide a variety of foraging conditions and security cover areas (Wisdom et al. 2005c).

10.2.3.3 Forage Allocation

Range managers have long attempted to develop proper animal stocking of western rangelands. Where multiple ungulates graze common landscapes, the questions of forage allocation and competition for limited forage among species have loomed large. Managers have used animal unit equivalencies based on body weight ratios to allocate forage and develop stocking rates; a cow is five times larger than a deer, so five deer equal one cow. The goal of this phase of the Starkey Project was to develop a forage allocation model to evaluate different grazing management strategies on interior forest summer ranges and test various hypotheses about the effects of alternative stocking rates for ungulates. Trying to model forage removal and animal performance for multiple species of ungulates across large heterogeneous landscapes is difficult due to the temporal and spatial variability in animal distributions, forage production, and forage nutritional value.

At Starkey, animal distribution was estimated with the use of resource selection functions (RSF). An RSF represents the probability that an animal will select or avoid resources over space and time in relation to available resources. RSFs can

then be integrated within a larger forage allocation model. Coe et al. (2005) developed RSFs for elk, mule deer, and cattle on the summer range at Starkey. During early and midsummer, the presence of cattle affected elk distributions, as shown clearly by the RSFs. Specifically, elk either moved to areas of the pasture where cattle did not go or elk left the pasture entirely. Likewise, elk affected where mule deer were located in the study pasture. Mule deer moved away from elk. These interactions indicate cascading effects of the larger herbivore displacing the smaller one. Management decisions that change cattle distribution or season of use change elk distribution which in turn changes mule deer distribution.

Late summer and fall are typically warm and dry in the interior Pacific Northwest. Forage for ungulates has matured and dried at this time causing a decline in their nutritive quality. Earlier in the summer when forage is both abundant and nutritious, animals separate themselves across the landscape. However, once nutrients become limiting, overlap in animal distribution increases. RSFs become more similar in relation to the scarcity of nutritional resources, forcing coexistence among ungulate species and increasing the potential for competition.

The traditional animal unit equivalency calculation based on animal weights requires that animals overlap 100 % in their distribution and diets. RSFs developed for elk, mule deer, and cattle indicate that animals vary seasonally in their distributional overlap and that cascading effects occur whereby larger animals displace smaller species.

Dietary overlap is the other major issue to be addressed in developing a forage allocation model. Findholt et al. (2005) designed a manipulative study on Starkey that addressed that issue by utilizing tame elk, mule deer, and cattle in enclosure studies with the specific intent of estimating diets and overlap among the species.

In ungrazed pastures, dietary overlap between cattle and mule deer was lowest but increased in response to previous cattle grazing. Nutritional analysis of the diets indicated no change in nutrient densities suggesting that competition was not occurring. With dietary overlap as an indicator, the greatest potential for competition was between mule deer and elk. However, if competition does occur, it may be interference competition as mule deer move away from elk (Coe et al. 2001). Since mule deer and elk tend to have similar RSFs in late summer when resources are scarce, it would appear that this early summer movement is preference related. It would seem that if in moving, mule deer encountered scarce nutritional resources, they would in fact move back near elk as they do in late summer when nutritional resources are scarce. Cattle and elk have similar diets particularly on pastures previously grazed by cattle. However, when cattle and elk grazed pastures previously grazed by cattle there is no compromise in either species' diet nutritional quality. Over time cattle nutrition decreases on pastures previously grazed by cattle, indicating intraspecific competition. The lack of 100 % dietary overlap among the ungulate species again negates the use of animal unit equivalencies based on animal weight.

From the data accumulated in the Starkey Project, development of a foraging model was initiated (Ager et al. 2005). The model predicts animal weight dynamics and animal distributions in response to stocking rates, grazing systems, and the

influences of other human activities such as road use. The major challenge to refine the current model is to determine what mechanisms in the foraging process are the most important determinants of landscape scale foraging behavior and animal performance. An objective is to identify the existence of key stocking thresholds that correspond to changes in animal performance at the species level. Such a tool is currently not available (Ager et al. 2005).

10.2.3.4 Age of Breeding Bulls

Elk herds in northeastern Oregon were declining when the Starkey Project began. Potential causes were identified as nutritional condition of females on conception dates, pregnancy rates, and age of male sires. In many elk management units in northeastern Oregon, only one or two bulls remained at the end of hunting season. That meant that most breeding in the following fall rut was by yearling bulls. Wildlife managers and sportsmen were concerned over the future of elk herds given the potential for declining productivity. Therefore, a study was developed to assess the effects of male age and female nutritional condition on conception dates and pregnancy rates of female elk (Noyes et al. 1996, 2002, 2005). Again, an enclosed study area was required to conduct the research so that manipulation of the male population could be accomplished. The elk herd during the study was managed so that a single cohort of males functioned as principal herd sires as they matured from 1 to 5 years of age.

Breeding by mature males achieved early and synchronous conception of females. Conception dates for females were strongly influenced by the age of sires; conception dates became progressively earlier as sires matured from yearlings to 5-year olds. Earlier birth dates are linked to increased neonate survival. In fall, calves born earlier are larger than calves born later. Calf body size is an important factor in surviving the first winter. Synchronous births also influence calf survival. A critical period for calf predation is the first 2 weeks after birth when the calf has limited mobility. Typically, calves remain hidden and motionless only getting up when the dam arrives for nursing. During this time, calves are particularly susceptible to predation. Synchronous breeding means synchronous calving over a short time frame. Calves born during a short time span flood the system during that 2-week susceptibility period and predation is reduced in contrast to a calving season that continues over an extended period, the latter of which allows for increased opportunities for predation.

Elk hunting seasons in Oregon and other western states were drastically modified based on the results from the breeding bull study at Starkey. Restrictions were placed on mature bull harvest and limited entry to specific game management units was implemented. Now, more mature bulls remain in the herds after the hunting season. Some of these bulls are available to hunters the next year. Use of these results in management enhanced both herd productivity and hunter opportunity to harvest a mature bull.

10.3 Synthesis of Research Trajectory

Over the past 22 years, results from the Starkey Project have been presented to managers in a variety of venues. These results have, in turn, been used by state and federal managers to formulate hunting seasons designed for a more sustainable harvest and in the forest planning process. Three workshops have been conducted to target different audiences. The workshop “Elk, mule deer, and cattle in forests: A workshop for managers” was held in La Grande, Oregon on September 5 and 6, 2001. Registration was 160 people from 6 states representing 15 National Forests, 3 Native American tribes, 2 universities, Department of Army, Bureau of land Management, and 5 state fish and game agencies. On February 26, 2003, a wildlife professionals’ workshop “The Starkey Deer and Elk Project: Results of long-term research for management” was sponsored by and conducted at the Rocky Mountain Elk Foundation Annual Meeting. Another workshop for wildlife professionals was held on March 22, 2004, at the North American Wildlife and Natural Resources Conference. Papers from this last workshop were published in the Conference Proceedings and as a book titled *The Starkey Project: A Synthesis of Long-term Studies of Elk and Mule Deer* (Wisdom 2005). The book is in its third printing.

Roads and traffic management studies produced findings about mule deer and elk response to open roads and traffic rates that are now being used in the current round of forest planning. Elk selected habitats away from roads (Rowland et al. 2000; Rowland et al. 2005; Wisdom et al. 2005b) while mule deer selected habitats away from elk and closer to roads (Johnson et al. 2000). From this work, research was developed to evaluate and compare the effects of off-road vehicle use (ORV), horse riding, mountain biking, and hiking on elk and mule deer. All four forms of recreation disturbed elk and elicited a flight response. ORV and mountain biking impacts were greater than the other two forms of recreation (Wisdom et al. 2005a; Naylor et al. 2009). Results of the roads and traffic study and the recreation study are being used across the western USA by National Forests in forest and travel management planning.

Timber harvest has little negative effect on mule deer, elk, and cattle, based on Starkey studies, as long as the increased vulnerability of elk and mule deer is recognized and road access is managed (Wisdom et al. 2005c). These results are easily extrapolated to include mechanical fuels reduction. Additionally, the perceived physiological requirement of elk for thermal cover was not supported by research (Cook et al. 1998, 2005).

New tools for innovative and equitable allocation of stocking rates among elk, deer, and cattle are being refined from Starkey Project research (Ager et al. 2005; Coe et al. 2001, 2005; Findholt et al. 2005). This phase of the original studies is still ongoing. The goal is to develop a HE model for cattle that is useful in predicting cattle distribution across seasons and is user friendly for managers.

The results of the breeding age of bulls study have been utilized by state fish and wildlife agencies to establish new elk hunting regulations that insures the carryover of mature bulls (Noyes et al. 1996, 2005). Prior to the study, bull elk hunting seasons in Oregon allowed unlimited entry into all management units for the entire

season and did not have antler (age) restrictions on bull harvest. Study results were used to modify hunting seasons so that entry to specific game management units was restricted and the number of mature bull tags was restricted. Washington and Idaho also modified seasons in a similar fashion for some of their game management units. Results have been very positive in that now there are more mature bulls available for breeding and harvest which has led to increased hunter satisfaction. Elk hunting tag application is, however, more complicated and hunting opportunities for mature bulls do not occur for an individual every year.

Starkey has yielded rich data that addressed the fundamental research questions on which it was founded (Thomas and Wisdom 2005). But, after more than 20 years of active research, the project was in a state of uneasy transition. The original research problems Thomas and his colleagues developed earlier had been addressed, countless publications outlining their findings had been prepared, and a great deal of findings had been disseminated. The Starkey Project had lived up to its expectations, so its researchers, frankly, were unsure of how they should proceed with potential future research.

An external review team was commissioned and met in June 1998 to review accomplishments and recommend research direction for the future. The review team was composed of an individual each from Wildlife Management Institute, Colorado Division of Wildlife (representing state wildlife agencies), US Geological Survey, Forest and Rangeland Ecosystem Service Center, and NFS. The team praised the project for developing a "world-class research facility," fostering interagency cooperation in research, the high level of professionalism and productivity, and the depth of the data collected. They went on to report that the facility and the tractable elk herd made the Starkey Project uniquely suited to become a world-leading center for long-term, large-scale research on ecosystem processes relating the dynamics of herbivores and plants. Suggestions for future research included:

1. Large-scale influences of ungulate densities on behavior of individuals, reproduction dynamics, and spatial relations among species of herbivores
2. The effects of domestic and native herbivores on the composition and structure of vegetation, ecosystem processes, and long-term productivity
3. More thorough analyses of existing data on animal distribution and forest landscape characteristics
4. Utilization of the tractable elk to study the grazing preferences and behavior as related to silvicultural prescriptions, cover characteristics, and experimental grazing regimes
5. Research related to human disturbance and animal distribution

During this time, Tom Quigley, first as the program manager of the Managing Disturbance Regimes research program and then as PNW station director, provided key leadership and funding support during critical periods. As the program manager, Quigley established positions for two new scientists at Starkey and secured funding for the initiation of new research directions. Then, as the station director, he provided funds for the development and construction of a replacement telemetry system based on global positioning system technology. Thanks to Quigley's support, those

funds became a permanent part of the Starkey Project's research budget. With this renewed support, a new era of research began at Starkey and continues today—one that addresses contemporary issues, including fuels reduction impacts on wildlife; ungulate impacts on ecosystems; human disturbance impacts on elk and deer; and the ecology of invasive plants.

10.4 Societal Impacts

Results of Starkey research have had direct benefits to both state and federal land and wildlife management agencies for land use and population management. Environmental, wildlife, hunting, and nongovernment organizations have benefited from the many applications of results in land and wildlife management. Results have also been applicable to the operations of private landowners and managers, forest product industries, and Native American tribes.

Research findings on the effects of roads traffic and off-road recreation on mule deer and elk now constitute part of the foundation for the national roads policy established by the US Department of Agriculture, Forest Service, thus affecting road and recreation management on all National Forests. Public use of National Forests will be affected by these new travel policies.

Data on elk and mule deer distribution as affected by physical features of the landscape, management, and seasonal nutritional value collected during the Starkey Project are now being used to develop new HE models for eastern Oregon forests. The models will have general application for most forests in the interior West. At minimum, model design can serve as a template for developing more local models. Models will provide information to managers developing forest plans.

Opportunities for wildlife viewing and hunting have benefited from Starkey research on the age of breeding bulls. More mature bulls are now present in herds in the Northwest, providing enhanced recreational opportunities for viewing and hunting.

Improved cattle management in forests in eastern Oregon should occur as further refinements are developed for cattle distribution models. Better cattle management should improve forage availability for mule deer and elk, improve vegetation diversity, and improve riparian vegetation conditions.

Native American tribes are increasingly active in the management of elk and deer on tribal lands, most also graze cattle, and they regulate tribal harvest on public lands where they have hunting rights.

Results from the Starkey Project have enhanced ecosystem services in the form of ecological functions that sustain and improve human life in association with National Forests and their management. Ecosystem services provided by the Starkey Project have future implications for mediating climate change and sustaining associated forest resources. For example, better management of ungulates could enhance the regulating ecosystem services of carbon sequestration and water management through more sustainable use of plant communities. Supporting ecosystem

services, primary production and nutrient cycling, likewise, will benefit from better ungulate management. Cultural services like recreation will also be improved.

10.5 Future Direction

Upon completion of the original four research thrusts, Starkey scientists utilized recommendations from the 1998 review, input from public and industrial forest biologists, and a review of literature to develop new directions for the project. A problem analysis "The role of ungulate herbivory and management on ecosystem patterns and processes" was completed and signed off by the PNWRS in 2003. That document now provides the general research direction for the Starkey Project.

10.5.1 Herbivory

At the close of the first four studies, new directions for research at Starkey were needed. Years of forest management in regard to timber harvest methods, livestock grazing, and fire suppression, while considered to be good practices at the time, have left National Forests out of alignment with what is considered a more ecologically based range of variability (Hann et al. 1997). Changes in the composition and density of forest canopies in the interior West had resulted in forests that were more prone to catastrophic wildfire. Recent management directions utilizing both mechanical and prescribed fire methods are being instituted to reduce fuels present on forestlands with the intention of reducing fire risk. Little was known on how these efforts might impact the behavior and distribution of mule deer, elk, and cattle. Research on Starkey involving dietary overlap of elk, mule deer, and cattle (Skovlin et al. 1976; Findholt et al. 2005) revealed that these animals would consume a wide range of forage species and could potentially alter the composition of plant communities through the herbivory process. Riggs et al. (2000) reported on long-term data taken from grazing exclosures in northeastern Oregon confirming that ungulate herbivory should be considered a chronic disturbance to plant communities and that plant succession following episodic disturbance, e.g., logging, fire, could be altered by ungulate herbivory.

A new direction for Starkey research was initiated based on the new emphasis of fuels reduction on forests and the potential interaction with ungulate herbivory and the possibility for alternative plant successional trajectories (Fig. 10.3). During 2001, 2002, and 2003, a total of 2,000 acres at various locations on Starkey was treated mechanically for fuels reduction and then followed with prescribed fire. Long-term research is focused on the impacts of ungulate herbivory on plant succession following the episodic disturbance of fuels reduction (Vavra et al. 2005). As Riggs et al. (2000) pointed out, the knowledge generated to date is rudimentary. Studies must be designed to integrate herbivory into disturbance

Fig. 10.3 An illustration of different trajectories of secondary succession following wildfire as influenced by herbivory or a lack thereof (inside fence)

research at scales meaningful to management. The Starkey study is designed to follow successional trajectories on plant communities subjected to mechanical fuels reduction treatments followed by prescribed fire and on similar untreated control plant communities. Replicated study sites each containing three levels of elk or cattle herbivory, low, medium, and high, have been established and a sampling protocol developed to follow successional trajectories (Vavra et al. 2005).

10.5.2 Fuels Reduction and Animal Behavior

As part of the fuels reduction research over a 2-year period, the influence of fuels reduction on mule deer and elk distribution was evaluated (Long et al. 2008a, b). Elk did not alter their behavior within a home range but rather altered their home ranges as a result of fuels reduction. Plant communities that had fuels reduction were used by elk in spring and early summer but avoided in late summer because of a decline in forage quality. Elk used non-treated controls during that time. Other influences on elk distribution noted in earlier studies also pertained here. Elk use of fuels-treated communities was affected by the presence of cattle and distance to roads. Mule deer use of fuels-treated communities was dependent on elk distribution as had been noted in previous studies. Fuels reduction opened up forest canopies and allowed more sunlight to reach understory vegetation, causing forage to mature earlier in the summer and lose its nutritive quality faster than in untreated controls. Elk responded to this array of forage by using treated stands early in the year and controls later. If elk are a consideration on forest landscapes being treated for excessive fuels, a mosaic of treated and untreated units would provide elk with an array of foraging choices across spring, summer, and fall that provide high-quality forage early in the growing season (fuels-treated units) as well as late in the season (untreated units).

Fig. 10.4 National Forest recreationists often encounter wildlife. Such encounters may lead to altered distribution of the impacted species

10.5.3 Human disturbance

Human access to National Forest lands has been facilitated by years of timber harvest and road construction. Human disturbance via road traffic is a potential modifier of elk distribution as noted by previous Starkey research. Recreation use has changed drastically on National Forests. The leisurely pursuits of a camping trip have been replaced by recreationists that use more of the landscape. Use of motorized off-road vehicles, motorcycles and all terrain vehicles (ATVs), mountain bikes, horses, and even hiking have put more people into the habitats occupied by mule deer and elk (Fig. 10.4). In the past, many National Forests have had few restrictions on road and off-road travel. The current forest planning cycle, however, has seen an increased awareness by managers that restrictions on off-road travel and road closures are needed to maintain ecological integrity of landscapes. Motorized users of public lands have been very vocal in their opposition to regulation and restriction of access.

Initial research at Starkey found that mountain biking, ATV use, hiking, and horse riding all disrupted elk behavior (Wisdom et al. 2005a; Naylor et al. 2009). Mountain biking and ATV use were the most disruptive. Elk spent less time foraging, more time in security cover, moved farther from use areas, and expended more energy when exposed to human disturbance than when none was present.

Results from this study are being used by forest planners to develop off-road recreation management plans that provide suitable refugia for wildlife. Results from this study were also used to develop an ongoing study on the use of ATVs during hunting season and that influence on the behavior of mule deer and elk.

10.6 Conclusions

Early research at Starkey focused on the problems of the day. Improper cattle grazing and the decline in the integrity of the forage base were addressed. This research was supported by Forest Service managers and livestock owners alike.

Many of the management recommendations that came from that research are still in use today.

Later, research dealing with wildlife and forest management interactions provided managers with information critical to retention of species of interest. Concerns over the impacts of grazing on stream and riparian zone integrity lead researchers to initiate studies on novel grazing systems to alleviate the season-long use of riparian corridors. These studies were the first long-term data sets evaluating cattle performance seasonally on eastern Oregon forest ranges. The research provides information to managers attempting to blend environmentally sustainable grazing systems with sustainable beef production for the permittees.

The Starkey Project—now in its 26th year—owes a great deal to the team of visionary researchers who established it and supported its research over the years. The implications of Starkey's work are far-reaching, with forest managers in the Interior Northwest and beyond routinely using findings yielded from Starkey's research to manage natural resources. The foundation of the Starkey Project is solid, significant, and resilient, meaning the site will continue to provide important contributions to natural resource management in the Interior Northwest for many years to come.

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